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RECYCLED PAPER CRUMBLE; BENEFITS AND LIMITATIONS AS A LIVESTOCK BEDDING AND A SOIL ENHANCER

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Abstract

Soil productivity and quality is influenced by the application of different fertilisers and soil structure enhancers to provide optimal crop growth and protect ecosystems and the environment. Commonly, straw is used as a livestock bedding material and is applied to land once it has been discarded. The use of straw is becoming less sustainable due to competition from the bioenergy market and adverse weather patterns affecting costs. This means an effective alternative is needed. This study presents an insight into Recycled Paper Crumble (RPC) applied to soil, once discarded from livestock enclosures in the form of farmyard manure (FYM). Analysis of soil nutrients and ecosystem studies were undertaken, and additionally, method of application, contrasting digging in (ploughing) and applying to surface (mulch) to provide knowledge for agriculturalists, horticulturalists and ecologists. Ecosystem studies were undertaken at week nine using the mustard extraction method. Few distinguishable differences were found between RPC and FYM applications with both adding to the nutritive values of the soil and being effective for earthworm (Lumbricus terrestris) activity. Significant increases in pH ($P < 0.001$) were found in RPC FYM applications suggesting potential as a lime replacement. In addition, no significant differences ($P > 0.05$) were found in organic matter, between applications and its depletion, seen over time. Ecosystems analysis concluded that RPC show significant difference compared to straw in the number of earthworm's present ($P < 0.01$). The findings in this study indicate RPC is a suitable alternative to straw as an all-round dual-purpose livestock bedding material and soil enhancer.

***Key words**: bioenergy, earth worms, ecosystem, livestock bedding material, recycled paper crumble, soil structure enhancer.*

INTRODUCTION

The aim of this research was to consider alternatives to straw for use as a dual-purpose product (livestock bedding/FYM), and to develop an understanding of new varieties of organic fertilisers with the intention of enhancing the nutritive value and structure of soil whilst being beneficial from an ecological aspect. The objective of this study was to prove whether Recycled Paper Crumble (RPC) provided a viable alternative to commonly used straw in terms of analysing breakdown and nutritive content of RPC Farmyard Manure (FYM) in comparison with straw FYM, to observe the effects on soil health and ecosystem habitats. Understanding the implication of fertiliser application to soil and how it can influence nutrient quality, fertility, outputs, soil structure, ecosystems and the environment is of vital importance for sustainable agriculture (Holland et al., 2018).

Research by Khan et al. (2013) refers to product uniformity to gain consistent soils. A level of inconsistency is shown in various fertilisers when adding NO_3-N. Ploughing in retains 90% of available N (Masvaya et al., 2017). A study undertaken by Luebbe et al. (2011) found fresh FYM (stored less than three months) applied to surface on medium/heavy soils will only supply 15% of total N. Ploughing is an effective method to boost NO_3-N. Research to magnify the differences between applications to surface and ploughing in is needed to limit environmental impacts and enhance value of N in FYM which is often lost to volatilisation leading to eutrophication (Wu et al., 2019).

Soil minerals account for half the soil volume and serve as sources and sinks of essential plant nutrients (Sanz et al., 2018). The type, proportion and concentration determine properties such as texture, structure and cation exchange capacity (CEC). Potassium (K) availability in plants is highly dependent on its release from the weathering of primary soil minerals (Behera et al., 2015). K, an abundant essential element, varies from 0.5-2.5% of soil mass providing plant life with various functions (Hillel, 2008). Huang et al. (2005) states 98% of total available K is bound in mineral form, the remaining 2% is in soil solution and exchangeable phase affecting availability. K deficiency is often caused by extreme pH levels, liming, lack of oxygen or true soil deficiency (Potash Development Association, 2011). Research by Quan et al. (2005) suggests no visible off-site environmental problems are present after K leaves the soil system being non-toxic and not causing eutrophication in aquatic systems. Phosphorus (P), a macro-element, required for plant nutrition, is found in organic compounds and minerals (Bernardo et al., 2019). UK surface soils have a P content averaging 0.6% (Stuart and Lapworth., 2016). Studies have highlighted concerns regarding application of FYM with abundant P carrying the risk of runoff responsible for eutrophication. A review by Smith et al. (1998) concluded restricting extractable P levels to 70 mg/l minimizes the risk of unnecessary P enrichment and subsequent leaching. This means that land managers may need to reassess their fertiliser applications. Rupp et al. (2018) identified that whilst FYM is an important organic fertiliser, excessive utilization may cause P accumulation and eutrophication of surface waste. Similarly, a pollution survey by Chen et al. (2019) concluded 55% of P pollution from agriculture is coming from FYM. These concerns suggest effective control measures, FYM types and application methods, need consideration to limit negative impacts.

Magnesium (Mg) is mainly present in inorganic compounds although sufficient amounts appear in organic material (OM) (Smith et al.,1998). Effective crop production requires enough Mg for plant metabolic processes and reactions which are adversely affected by Mg deficiencies. Decreased Mg directly correlates with low pH, cold temperatures, desiccation and predominant competing elements such as K and calcium (Ca). Synthetic fertilisers supply Mg but are often insoluble and contain chlorides (Tried and Tested, 2014). This negatively impact on crop quality.

Rothamsted Research (2019) draws on an extensive range of sources to assess earthworm biodiversity in grasslands. Their studies suggest average topsoil has nine earthworms for every five-inch^2 (2790/m$^{2)}$ of soil compared to high quality soils which are three times higher. Their research concluded 42% of soils have poor earthworm biodiversity with few or no surface dwelling and deep burrowing worms. The absence of deep burrowing worms on 16% of soils significantly affects water infiltration due to lack of vertical burrows (Onrust and Piersma, 2019). Several FYM application methods can be used such as a mulch or ploughing in. A mulch provides OM whilst creating a cool, moist climate which is effective for earthworms (Bertrand et al., 2015). FYM's high in N have potential to create unfavourable conditions for earthworms. N content is at its highest in fresh FYM's so takes several weeks to age to be effective for ecosystems. The use of synthetic fertilisers creates hostile ecosystems as they increase acidity (Onrust and Piersma, 2019). Many nutrients eaten by livestock are excreted increasing the value of FYM as fertiliser (Chadwick et al., 2015). Equal amounts of FYM from different species have different effects on soil composition and nutrient uptake (Larney and Olsen, 2006). A proportion of nutrients obtained from the soil can be lost atmospherically before they can be made available for crop uptake as FYM's decompose during storage and moisture contents reduce. Several studies investigating N losses during storage of cattle FYM show a mass loss range of 7-39% (Larney and Olsen, 2006; Larney et al., 2008; Luebbe et al., 2011). Greater loss estimates reported with a range of 32-54% at 180 days (Rotz and Leytem, 2015) can be related to relatively low crop available nutrients (Table 1).

Table 1. Nutrient availability of different FYM types (Adapted from Tried & Tested, 2014)

	Total Nutrients (kg/t)			**Crop Available Nutrients(kg/t)**		
Type of FYM and DM content (%)	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
Cattle FYM (25%)	6.0	3.2	8.0	1.2	1.9	7.2
Sheep FYM (25%)	7.0	3.2	8.0	1.4	1.9	7.2
Pig FYM (25%)	7.0	6.0	8.0	1.8	3.6	7.2
Layer FYM (35%)	19.0	14.0	9.5	9.5	8.4	8.6

An investigation by Duruogbo et al. (2007) reported poultry FYM increased soil pH, OM and K, several micronutrients, and decreased salinity. A similar study by Whalen et al. (2000) indicated cattle (*Bos taurus*) and sheep (*Ovis aries*) FYM stored over a short period reduces soil acidity and increases the quantity of P and K and crop available nutrients in each FYM type. This research indicates that species influence FYM quality as differing species can harbour different nutrient qualities. This is dependent on soil type, material type, previous soil management and method of application. Straw is the most used FYM due to its traditional use as a livestock bedding material. Straw is a key source of OM, P, K, Mg and benefit organisms which break down cellulose (Copcea et al., 2017).

Challenges in the straw market including ploughing crop residues in and competition from the biofuel industry. These factors result in an increase in sparseness and cost, specifically in certain areas of the UK where few crops are grown (Venturini et al., 2019). The use of by products, including shavings and woodchip, are viable alternatives, however, these products have never been able to fully compete with straw as an all-round product (Teixeira et al., 2015). This is partly due to the time taken for them to break down especially if treated (Copcea et al., 2017). Overall, there is a requirement for an alternative, dual purpose livestock bedding material and FYM source. There is very little research around types of wastepaper to meet the demand for a dual-purpose material. Paper-based materials are often used as organic amendments rather than fertilisers due to their low mineral contents (Bellamy et al., 1995). Pulp and paper industries generate a mass of solid waste (Azevedo et al., 2019) creating a market for use in agriculture.

According to Royer-Tardif et al. (2019), paper-based material provides a latent alkalinity, controlling pathogens in the soil and increasing pH when applied, reducing the need for lime application (Quaye et al., 2011). The market value of paper-based materials is £40-85/Tonne (Azevedo et al., 2019). Price varies depending on whether the de-inking process is needed to remove toxic compounds (Villagra et al., 2011). Research by Quaye et al. (2011) into the impacts of paper sludge FYM on soil suggests a major drawback is its relatively high C (carbon): N ratio being detrimental by immobilising N. Applications of FYM with higher N have the potential to relieve deficiencies whilst maintaining organic residues from paper. A pilot study, requested by the product manufacturer Cows & Co Group (2018), was carried out in February 2018, comparing RPC to straw as a material in sheep enclosures. Product effectiveness was proven, with statistical analysis showing lower material temperatures than straw and no significant differences ($P > 0.05$) in the instances of lameness or health issues. Analysis showed no metals were traceable in RPC from the paper making process. This is important as they can be toxic to animals and the environment (Carolin et al., 2017). As part of the pilot study, analysis was undertaken on fresh weight samples of the 2 material types (Table 2) and a further analysis on RPC as to the quality it provides when spread as FYM on land (Table 3). Pilot study findings led to a research project into the use of RPC as a fertiliser and as a soil structure enhancer. It is vital that materials prove effective when applied to soil, to provide required outputs, optimize soil structure and enhance nutrient values.

Table 2. Analysis of RPC in comparison to straw on a fresh weight basis (Authors own, 2018)

Sample type	Dry Matter (%)	pH	Total Nitrogen (kg/t)	Ammonia Nitrogen (kg/t)	Total Phosphate		Total Potassium	
					as P (kg/t)	As P_2O_5 (kg/t)	as K (kg/t)	as K_2O (kg/t)
Straw	38.70	8.60	8.91	2.04	1.89	4.33	6.87	8.28
RPC	37.22	8.40	6.90	1.49	1.20	2.74	5.14	6.20

Table 3. RPC FYM value when added to a field based at Lee Farm; March 2018 (Authors own, 2018)

pH	Potassium		Phosphorus		Magnesium		Organic Nitrogen (N storage)
	mg/l	Index	mg/l	Index	mg/l	Index	mg/litre
5.60	250	3.0	38	3.6	180	4.0	4245

MATERIALS AND METHODS

Research carried out at Myerscough College/University of Central Lancashire. Research commenced 21st November 2018, until completion on 23rd February 2019. Soil analysis carried out in the Myerscough College laboratories. All chemicals and consumables were supplied by Fisher Scientific (2019).

Figure 1: Map of Myerscough and Bilsborrow, UK
(Red + mark trial plot area)
(Google Earth, 2019)

The trial plots were set up; bedding materials applied were used in sheep enclosures, prior to use in this study. The soil type of the trial plot area was analysed pre-trial. It consisted of 54% sand, 32% silt, 14% clay. The area was split into two sections, A and B. Section A had used material dug in (15 cm depth) and B had used material left on the surface. The plots were set up using a randomized complete block design. Plot numbers were selected for ease of statistical analysis. Plot names: for example, RPC surface, refers to RPC based FYM which had been applied on the soil surface/RPC dug, refers to RPC based FYM which had been dug in.

Area A and B were divided into nine trial plots, measuring 183 cm x 122 cm and had an application rate of 6 kg, according to RB209 guidelines (AHBD, 2019). All dug in plots (including control) had the soil turned prior to the investigation. Each plot had a soil sample and moisture content taken prior to treatment (week 0) and then on a three-week basis (weeks 3, 6 and 9) thereafter, allowing the FYM time to degrade into the soil. After initial application of treatments, trial plots were left untouched (other than soil sampling every third week). Soil samples were taken using an auger in a W shape. A Delta-T ML2x Theta Probe was used, inserting the probe into the soil in several places in a W shape. After 30 seconds of recording, the moisture content shown as % vol. on the HH2 meter and the average of each plot was calculated.

Figure 2: Kitchen Garden Trial plot

After soil sample collection of each plot in a W shape (15 cm depth), the soils were dried in a 30^0C oven for a week before they were ground up using a pestle and mortar and retained until all samples had been collected. All 72 samples were tested together to reduce testing variability. Methods of soil/nutrient content analysis were adapted from the work of Bailey (1985).

A 20 ml volume of air-dried soil, ground to pass a 2 mm mesh sieve, was transferred into a 175 ml bottle and 50 ml of calcium sulphate solution added. Bottles were capped and shook on the shaking machine for 15 minutes. Next, they were filtered through 125 mm Whatman No. 2 filter paper into a 60 ml bottle and the filtrate

retained for determination of nitrate-nitrogen. The VWR 2100 L Meter and Orion ISE nitrate electrode were set according to manufactures instructions. Exactly 10 ml of each working standard was added to 10 ml of ISA Buffer. Starting with the lowest concentration, the electrodes were immersed into 1 mg/l nitrate-nitrogen working standard solution ensuring the solution was stirred. The mV readings were recorded when a steady value was obtained. The electrodes were then removed and rinsed. The mV readings for corresponding nitrate working standard solutions (4, 10, 20, 50, 100) were recorded. The temperatures at which the measurements were made were recorded. The standards were constructed on a graph on semi logarithmic paper. The temperature of the extracts was brought to that of the nitrate working standard solutions. The electrodes were immersed into the extract keeping the extract stirred a reading was taken when a steady value was obtained. The electrodes were removed and rinsed after each reading was taken.
A 10 ml sample of air-dried soil, ground to pass a 2 mm mesh sieve, was transferred into a 175 ml bottle and 50 ml of M ammonium nitrate added. The bottle was capped and placed on the shaking machine for 30 minutes. The solution was filtered through a 125 mm Whatman No. 2 filter paper and the filtered extract then retained for the determination of potassium.
The potassium working standard solutions containing 0 and 50 mg/l of potassium were nebulised into natural gas flame. The controls on the Corning 410 Flame Photometer were adjusted until steady at zero and maximum readings were then obtained. The intermediate standard working solutions were nebulised and a graph constructed relating noted meter readings to mg/l of potassium in all the standard solutions.
The content of potassium, phosphorus, magnesium, organic material and pH measurement were calculated using standard laboratory procedures. After the completion of soil sampling, earthworm extraction took place in mid-February to allow the weather to be warmer increasing the chances of worm presence and limiting the chances of frost in the process.

RESULTS AND DISCUSSIONS

Data sets were compiled on Microsoft Excel (2017) and imported onto Minitab (2018) for statistical analysis with the inclusion of descriptive statistics to determine standard deviations (± SD). Individual data sets were tested for normality using the Kolmogorov-Smirnov test. Parametric data was analysed using a General Linear Model, One-Way ANOVA's and Tukey Pairwise Comparison's. Where appropriate, data was transformed onto a logarithmic scale for detailed analysis. For all tests conducted, statistical significance was set to $P \leq 0.05$. Letters indicated heterogeneity by Tukey ($P < 0.05$).
Data was analysed for all the parameters that were measured in the laboratory. Data that showed no significant difference or relevance to the hypothesis was not included in the following section. General linear models were used to check for the effect of time, treatment and method of application on each of the analysis undertaken. The space allocated for research was within a working garden and resulted in variation within the soil from week 0, allowing some significant differences between plots.

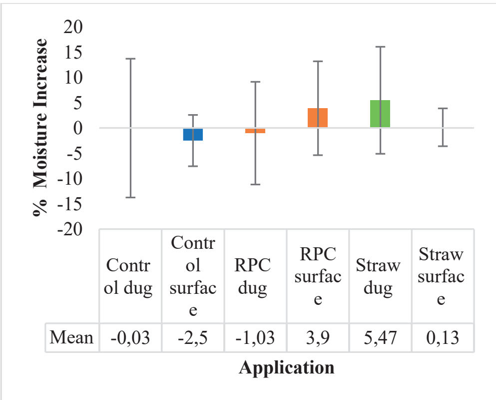


Figure 3. Mean (± SD) increase in % moisture of all application types by week nine

No significant difference ($P > 0.05$) could be seen between application types.
ST Dev: 13.72, 5.07, 10.15, 9.28, 10.58, 3.74 ($P = 0.893$, $F = 0.32$, DF = 5, n = 3).

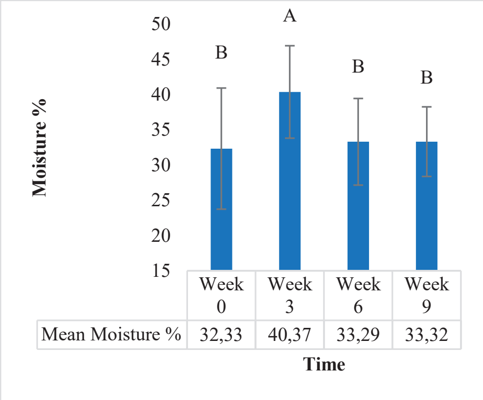


Figure 4. Mean (± SD) moisture of 18 plots over the duration of the trial

A significant increase (P < 0.01) in moisture content was present in week 3 (A) compared to other weeks (B). ST Dev: 8.59, 6.56, 6.15, 4.94 (P = 0.005, *F* = 4.78, DF = 3, n = 18).

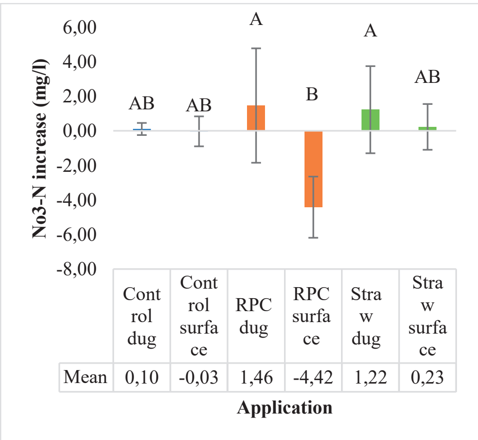


Figure 5. Mean (± SD) increase in NO_3^{-N} of all application types by week nine

There is a significant difference (P < 0.05) in RPC dug in (A) and straw dug in (A) when compared to RPC surface (B). No significant differences (P > 0.05) were found between control dug, control surface and straw surface (AB) in comparison to other applications. ST Dev: 0.35, 0.87, 3.31, 1.77, 2.52, 1.32 (P = 0.033, *F* = 3.56, DF = 5, n = 3).

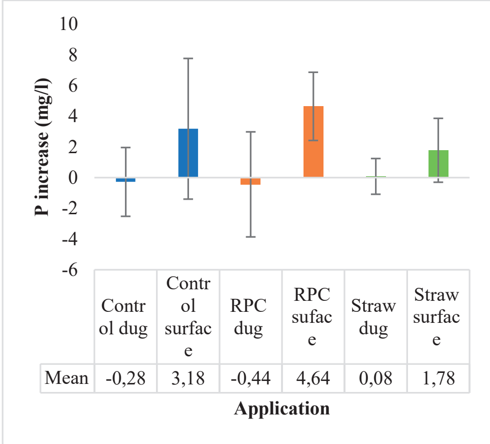


Figure 6. Mean (± SD) increase in P of all application types by week nine

There was no significant difference (P > 0.05) in any types of application. ST Dev: 2.24, 4.58, 3.42, 2.22, 1.16, 2.08 (P = 0.229, *F* = 1.62, DF = 5, n = 3).

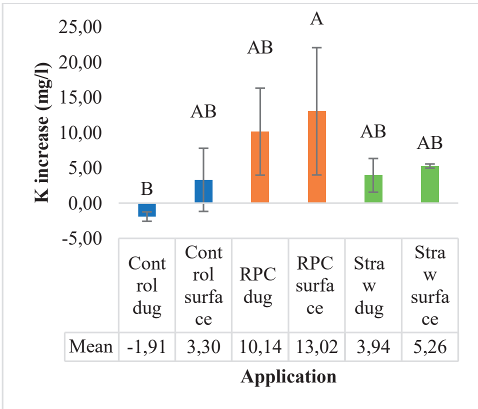


Figure 7. Mean (± SD) increase in K of all application types by week nine

There is a significant difference (P < 0.05) in RPC on surface (A) in comparison to control dug in (B) No significant differences (P > 0.05) were found between control surface, RPC dug straw dug and straw surface (AB) comparison to other applications. ST Dev: 0.66, 4.48, 6.17, 9.03, 2. 39, 0.29 (P = 0.036, *F* = 3.46, DF = 5, n = 3).

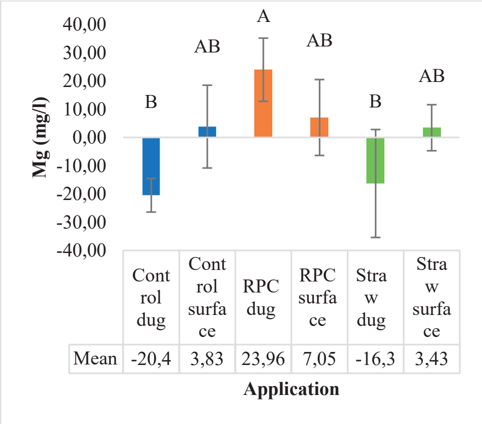


Figure 8. Mean (± SD) increase in Mg of all application types by week nine

There is a significant difference (P < 0.05) in RPC dug in (A) in comparison to control dug in and straw dug in (B) No significant differences (P > 0.05) were found between control surface, RPC surface and straw surface (AB) comparison to other applications. ST Dev: 5.95, 14.65, 11.19, 13.43, 19.10, 8.15 (P = 0.012, *F* = 4.87, DF = 5, n = 3).

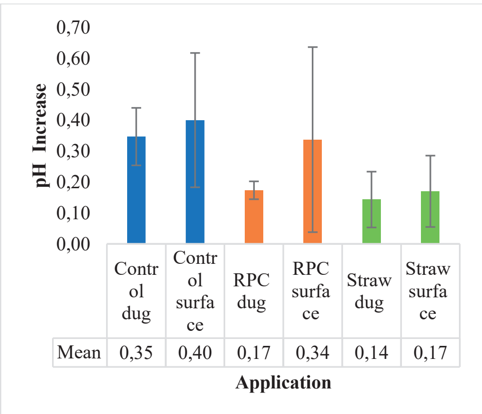


Figure 9. Mean (± SD) increase in pH of all application types by week nine

No significant difference was found in application types (P > 0.05). ST Dev: 0.09, 0.22. 0.03. 0.30, 0.09, 0.12 (P = 0.314, *F* = 1.34, DF = 5, n = 3).

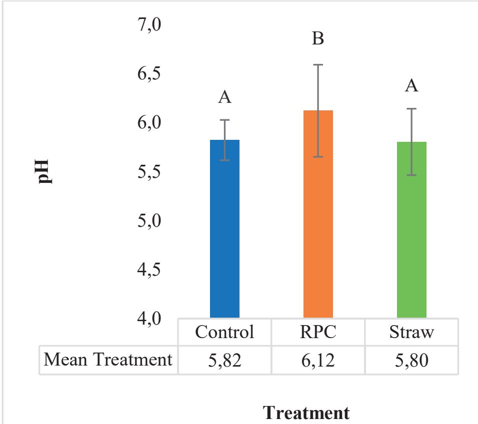


Figure 10. Mean (± SD) pH of 18 trial plots throughout the trial considering treatment

There was no significant difference (P < 0.001) in the mean pH amongst control (A) and straw (A) treatments, however there was a significant increase (P < 0.05) in RPC plots (B). ST Dev 0.21, 0.47, 0.34 consecutively (P < 0.001, *F* = 18.50, DF = 2, n = 24).

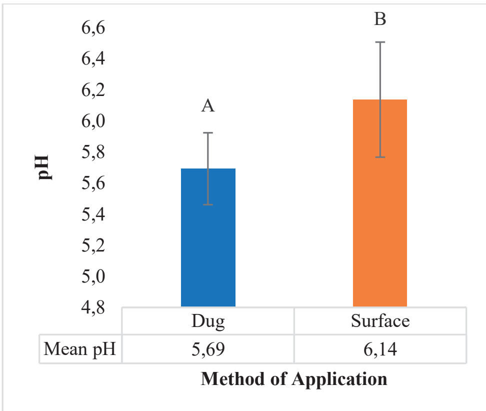
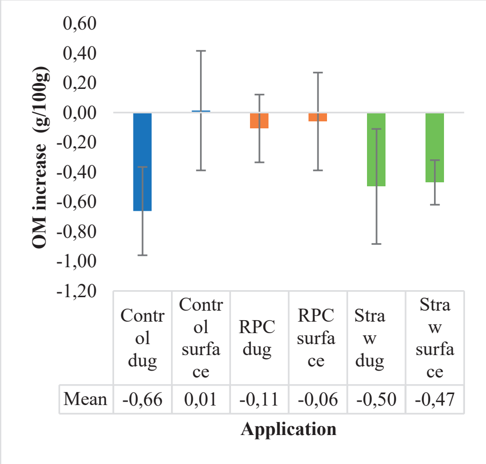


Figure 11. Mean (± SD) pH of 18 trial plots throughout the trial considering method of application

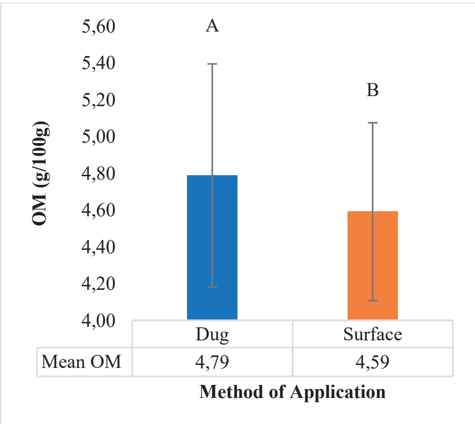
There was a significant difference (P ≤ 0.001) in the pH of surface plots (B) in relation to dug in plots (A). ST Dev: 0.23, 0.37 consecutively (P < 0.001, *F* = 86.02, DF = 1, n = 36).



	Control dug	Control surface	RPC dug	RPC surface	Straw dug	Straw surface
Mean	-0,66	0,01	-0,11	-0,06	-0,50	-0,47

Figure 12. Mean (± SD) increase inorganic matter of all application types by week nine

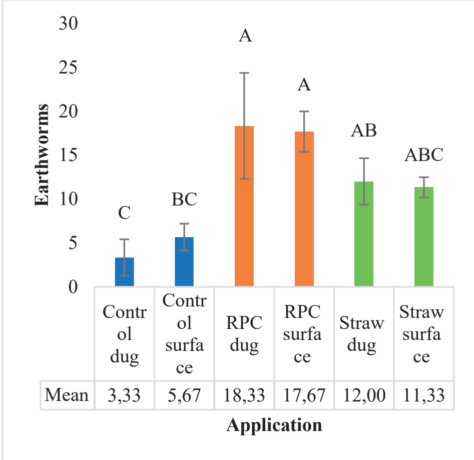
No significant difference was found in applications (P > 0.05). ST Dev: 0.30, 0.40, 0.23, 0.33, 0.39, 0.15 (P = 0.097, F = 2.43, DF = 5, n = 3).



	Dug	Surface
Mean OM	4,79	4,59

Figure 13. Mean (± SD) organic matter throughout the trial in relation to method of application

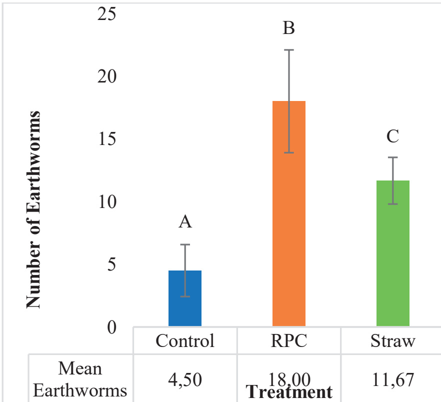
There was a significant difference (P < 0.05) in OM contents in dug in plots (A) in relation to surface plots (B) ST Dev: 0.61, 0.48 (P = 0.048, F = 4.13, DF = 1, n = 36).



	Control dug	Control surface	RPC dug	RPC surface	Straw dug	Straw surface
Mean	3,33	5,67	18,33	17,67	12,00	11,33

Figure 14. Mean (± SD) earthworm content in trial plots in relation to application at week 9

There was a significant difference (P < 0.001) in the number earthworms in RPC dug (A) and RPC surface (A) than control dug (C) and control surface (BC). Control dug (C) also had significantly lower (P < 0.05) earthworm presence than straw dug (AB) ST Dev: 2.08, 15.3, 6.03, 2.31, 2.65, 1.16 (P < 0.001, F = 11.79, DF = 5, n = 3).



	Control	RPC	Straw
Mean Earthworms	4,50	18,00	11,67

Figure 15. Mean (± SD) number of earthworms in plots of different treatments at week 9

Control plots (A) had a significantly lower (P < 0.001) worm count than RPC plots (B) and straw (C). Straw plots (C) were significantly lower than RPC plots (P < 0.001). RPC plots (B) had significantly higher (P < 0.001) worm counts than other treatments ST Dev 2.07, 4.10, 1.86 (P < 0.001, F = 28.98, DF = 2, n = 6).

CONCLUSIONS

Nitrate-Nitrogen contents differed pre-application at week zero. Potentially, this is due to previous crops or chemicals that have been applied; this is not ideal but makes the study more realistic to what happens in industry. The development of a precision agriculture technique that could apply FYM rates in differing depending on soil N requirements would be an effective technological

The phosphorus content of applications showed no significant increase over the period of the study for any application types This may show that a longer period is required for P to break down in the soil. Lack of significant difference and very minor increases (sometimes decreases) imply alternative applications or a longer time frame may be required to boost P nutrient content.

Both RPC and straw plots showed an increase in potassium suggesting the means for aiding growth and reproduction in plants. The gains demonstrated in both RPC and straw plots show equal potential for supplying soils with K; RPC plots showed the greatest increase with straw plots showing a lesser increase; the K increase demonstrates that the liming effect of RPC is not creating K deficiencies as stated by Potash Development Association (2011).

The average pH of RPC plots was 6.12 (mildly acidic), in comparison to straw at 5.80 implying that RPC is more appropriate for providing an acceptable pH for soil nutrient bioavailability and plant productivity. Surface plots had a significantly higher pH than dug in plots

Dug in plots have a higher OM than when applied on the surface. Both methods of application showed a moderate concentration of OM, this could be due to OM being in the process of breaking down, assisted by the help of earthworm thus having a greater effect on plots with treatments further into the soil

Overall, analysis shows that neither treatment is effective for the addition of OM. However, if necessary, to apply, digging in (ploughing) is the effective method. OM result in this study greatly differs from most research in the agricultural industry.

Earthworms presence was significantly higher in RPC dug in and on surface plots than in control plots. The elevated number of earthworms in RPC plots implies RPC soils fit the requirements of earthworm quantity specified by Rothamsted Research (2019). This suggests that RPC is effective at allowing earthworms to convert digestible C into a form that stays in the soil. Earthworms convert C emitting microbes into a form of organic matter (stabilisation) which decreases the amount of emissions entering into the atmosphere in the form of carbon dioxide correlates with earthworms thriving in a more neutral soil (between 6.0 and 7.0) as demonstrated in RPC plots.

Both straw and paper are effective at increasing the number of earthworms in a soil. However, as RPC had the greatest number of earthworms present this is the preferred treatment with application acceptable through either method.

With the correct marketing RPC could prove a viable product to horticulturalists because of ease of soil application present due to particle size in comparison to other products on the market. Market gardeners may find the product viable due to the size of RPC particles and the 25 kg bales available providing ease of use.

It is necessary to find a material that can replace straw due to lack of sustainability, this study provides a basis for progression within the agricultural industry to supply high quality, dual purpose materials that prove effective for both housing livestock and applying to soil to all in all optimize output across all aspects of modern-day agriculture.

There is little proof within this research to indicate that RPC would be effective as a mulch to conserve soil moisture, reduce overland flow and detach and transport sediments (Das et al., 2019). Crop cover (fleece) use has the potential to specify the performance of treatments with increased accuracy in relation to moisture associated factors. Positive results could promote the use of RPC on a global scale as a mulch to retain moisture in dry climates. An example of its use could be on vineyards and for cereals grown in Mediterranean climates (Prosdocimi).

Heavy rainfall in week three showed all application types can be considered free draining and not a cause of water logging. This contradicts literature suggesting the addition of material to the soils surface retains large amounts of water although it has been suggested that materials left on the soil surface formed a layer between the soil and the atmosphere thus at times both sunlight and moisture may have been prevented from reaching the soil surface of the trial plots.

Further testing is required to provide evidence on its long-term effectiveness.

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